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ACCURATE REFLECTANCE MEASUREMENTS:

An Ellipsoidal Mirror Reflectometer

IN BRIEF ... NBS has devised an ellipsoidal mirror reflectometer capable of measuring most defined reflectances accurately within one percent from 0.4 to 10μ for all engineering materials regardless of their level of reflectance or the geometric distribution of their reflected fluxes.

An ellipsoidal mirror reflectometer for accurate measurements on engineering materials was recently designed and constructed at the NBS Institute for Applied Technology (U. S. Department of Commerce) under the sponsorship of the Air Force and the National Aeronautics and Space Administration. This instrument is the work[1/] of S. T. Dunn, J. C. Richmond, and J. A. Wiebelt.*

Although the new reflectometer presently is less convenient to use than others, it is more accurate and versatile than those now in use. It may be used to measure bi-directional reflectance, directional hemispherical reflectance, the specular and diffuse components of reflectance, and directional annular cone reflectance.

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The demand for accurate and well-characterized infrared and solar reflectance data is relatively new and intimately tied to the space exploration program, where the basic problem of satellite temperature control has not been adequately solved. In addition to the space program needs, there is a continuing demand for accurate experimental verification of existing theories concerning the relations between reflectance and surface parameters such as roughness, damage, contamination, and temperature.

A lack of accurate, well-characterized data forces heat transfer engineers to assume either perfectly diffuse reflection or emission, or to assume specular reflection. Unfortunately, the most useful approach, that of assuming partial specular and partial diffuse reflectance, cannot be used, as few data of this nature are available.

Instruments presently used for reflectance measurements have several common disadvantages: restricted versatility, unknown or poorly known accuracy of measurement, and lack of absolute reflectance standards. The ellipsoidal mirror reflectometer was developed to minimize these problems.

The ellipsoidal mirror reflectometer has two major components. The first is the ellipsoidal mirror 12¼ in. in diameter and 3 5/8 in. high. One focal point is in the plane of the mirror's edge and the second is 17 in. beyond the first. The other component is a detector which views the interior of a sulfur coated averaging sphere.

Two methods may be used to determine directional hemispherical reflectance with this instrument. In the first method, absolute directional hemispherical reflectance is computed as the ratio of incident flux, measured at the first focal point, to the reflected flux, measured at the second focal point. To accomplish this, the detector is placed at the first focal point to measure the incident flux. Then a sample is placed at the first focal point and the reflected flux is focused at the second focal point by the ellipsoidal mirror where it is measured by the detector. This method requires accurate knowledge of all system losses. In the second method, relative direction hemispherical reflectance is determined by comparing the flux reflected by a sample to that reflected by a specular reflectance standard.

Other reflectances can be measured because the unique optical properties of the mirror permit accurate description of the reflected flux distribution. This is possible because the spatial distribution of reflected energy crossing the first focal plane is precisely related to the geometric distribution of the reflected flux. Thus, other reflectances can be measured if selectively shaped shields are placed in the first focal plane to blank out unwanted energy.

Several factors contributed to the accuracy of the instrument. The sulfur coated averaging sphere minimized spatial and angular sensitivity. A correction technique for the entrance hole loss was effectively utilized. The ellipsoidal mirror reduced both the system aberrations and the size of the solid angle of flux incident on the detector. The effective reflectance of the mirror was measured as a function of position on the mirror; this provided an accurate correction for variations of the mirror's reflectance with position. The reflectometer needs only a specular reference standard, which is easily calibrated. System losses can be evaluated by establishing the flux involved in each loss through use of shields placed in the first focal plane.

The accuracy of this type of instrument is estimated to be at least 2 percent and probably better than 1 percent over the range of 0.4 to 10μ. A positive statement of accuracy, however, cannot be made because of the lack of comprehensive data on the goniometric distribution of reflected flux from common engineering materials. The usefulness of an accuracy of better than 1 percent has been questioned, as the condition of the surface while in use may not be definitely known. Nevertheless, this reflectometer provides more information concerning the reflectance of materials than previous instruments.

1/ For further information, see Design and Analysis of an Ellipsoidal Mirror Reflectometer, by S. T. Dunn, PhD Thesis, Oklahoma State University (May 1965), available from University Microfilms, Inc. Ann Arbor, Mich.

CAPTION FOR ILLUSTRATION:

Figure 1. The two major components of the ellipsoidal mirror reflectometer developed at NBS are the ellipsoidal mirror (top) and the detector (left center) which views the interior of the sulfur coated averaging sphere (center).

Photo: 33110-3186

NOTE TO EDITOR: Glossy prints of the listed illustration are available to editors upon request. Address the National Bureau of Standards, Office of Technical Information and Publications, Washington, D. C. 20234.

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